LEVEL

AGARD-R-677

AGARD-R-677

AD A103706

AGARD

ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

7 RUE ANCELLE 92200 NEUILLY SUR SEINE FRANCE

AGARD REPORT No. 677

Factors of Safety Related to Structural Integrity

A Review of Data from Military Airworthiness Authorities

NORTH ATLANTIC TREATY ORGANIZATION

DTIC FILE COPY

NP

DISTRIBUTION AND AVAILABILITY ON BACK COVER

81 9 01 118

AGARD-R-677

NORTH ATLANTIC TREATY ORGANIZATION

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

11 Jan 81

12 47

AGARD Report No.677

6 FACTORS OF SAFETY RELATED TO STRUCTURAL INTEGRITY.

A Review of Data from Military Airworthiness Authorities.

Accession For	
NTIS GRA&I	X
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A	

DISTRIBUTION STATEMENT A

Approved for public release; Distribution Unlimited

This Report was sponsored by the Structures and Materials Panel of AGARD.

THE MISSION OF AGARD

The mission of AGARD is to bring together the leading personalities of the NATO nations in the fields of science and technology relating to aerospace for the following purposes:

- Exchanging of scientific and technical information;
- Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;
- Improving the co-operation among member nations in aerospace research and development;
- Providing scientific and technical advice and assistance to the North Atlantic Military Committee in the field of aerospace research and development;
- Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field;
- Providing assistance to member nations for the purpose of increasing their scientific and technical potential;
- Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community.

The highest authority within AGARD is the National Delegates Board consisting of officially appointed senior representatives from each member nation. The mission of AGARD is carried out through the Panels which are composed of experts appointed by the National Delegates, the Consultant and Exchange Programme and the Aerospace Applications Studies Programme. The results of AGARD work are reported to the member nations and the NATO Authorities through the AGARD series of publications of which this is one.

Participation in AGARD activities is by invitation only and is normally limited to citizens of the NATO nations.

The content of this publication has been reproduced directly from material supplied by AGARD or the authors.

Published June 1981

ISBN 92-835-1390-8

Printed by Technical Editing and Reproduction Ltd
Harford House, 7–9 Charlotte St, London, W1P 1HD

PREFACE

The SMP-activity on 'Factors of Safety' was started as early as Fall 1976 as an informal ad-hoc-group. At the Fall 1976 and the two subsequent Panel-Meetings, three pilot papers were delivered, namely by

H. Struck from VFW, Germany on 'Factors of Safety, Limit Load Concept-Maximum Load Concept'

W.G. Heath from British Aerospace, United Kingdom on 'Factors of Safety - Should they be reduced?'

C.J. Schmid and G.E. Muller from AFFDL, United States on 'Factors of Safety - USAF Design Practice'

These three papers were subsequently published under one cover as AGARD Report No. 661. Factors of Safety Historical Development, State of the Art and Future Outlook.

After lively and intensive discussions on these pilot papers a Sub-Committee was formed, which decided during the Fall 1977 Panel Meeting that it would not be worthwhile - for the time being - to take any action towards changing the present concept of factors of safety, but to establish a questionnaire to be sent to the military and civil airworthiness authorities of the NATO Member-Nations, asking for all factors of safety to be defined in the form of numerical values. Messrs. H. Struck and C.J. Schmid were nominated as Coordinators for Europe and North America respectively.

By Fall 1978 the questionnaire had been finalized and sent out to 21 military and civil authorities, enabling preliminary answers to be discussed.

By Spring 1980, 18 of the authorities addressed had answered the questionnaire, but as some major civil authorities did not respond, all answers from civil authorities had to be excluded from further consideration. After Spring 1979, the two Coordinators drafted several versions of collected answers, arranging them in the same order as the questionnaire.

During the summer of 1980 the Coordinators had personal discussions with nominated representatives of the major military airworthiness authorities in order to clarify the answers and to avoid possible misinterpretations.

For the Fall 1980 SMP-Meeting the Sub-Committee invited representatives of the military airworthiness authorities to participate in a round table discussion in order to provide further clarification of the answers before publishing.

The final collection of answers to the questionnaire contained in this report includes the results of the personal discussions mentioned above as well as the outcome of the round table discussion.

For reasons of completeness a summary of the round table discussion is provided at the end of this report, indicating those taking part as representatives of the military authorities.

Help and guidance of all contributors to this report is highly appreciated, especially the kind assistance of the authorities and their representatives and the heavy workload of the two coordinators.

R.J. MEYER-JENS
Chairman, Sub-Committee
on Factors of Safety

CONTENTS

FACTORS OF SAFETY RELATED TO STRUCTURAL INTEGRITY

A Review of Data from Military Airworthiness Authorities

SUMMARY

The concept of structural safety as presently applied by the military airworthiness authorities of the main NATO-Member-Countries has proven satisfactory, though being far from having a rational basis.

Before this background, a Sub-Committee of SMP established a Questionnaire (see chapter 1), asking the military authorities for all numerical factors applied to ensure structural safety of aircraft. The answers given are condensed in chapter 2 of this report, including the results of personal discussions between coordinators and nominated representatives of the authorities. The precis of the round table discussion as well as an evaluation of answers and discussion are included for reasons of completeness.

From the evaluation it may be concluded that there exists a considerable amount of agreement with respect to the Factors of Safety and their application. On the other hand, some disagreements and different interpretations have resulted. Thus this report forms a basis for discussing the disagreements in order to achieve a higher degree of conformity between the authorities of the NATO-Countries with regard to structural safety and reliability.

1.0 QUESTIONNAIRE ON FACTORS OF SAFETY

During the 46th SMP-Meeting, Spring 1978, the two coordinators presented a first draft of the Questionnaire which was discussed in detail by the Sub-Committee. The final version of the Questionnaire as laid down in the following paragraphs was distributed to the airworthiness authorities through cover letter dated 15th Nov. 1978 (see 1.4).

1.1 Introduction

The progress made with respect to determination of aerodynamic derivatives, loads, stresses and deformation during the last decades together with the fact that there exists a lack of rational basis for the Factors of Safety Concept presently applied to the design of airvehicles, brought about a discussion of changing the structural safety concept and the factors involved within AGARD-SMP some three years ago.

To condense these discussions AGARD-SMP formed an ad hoc group of Panel Members and later a Sub-Committee. In Fall 1977 three pilot papers contained in AGARD-Report No. 661 "Factors of Safety" addressed the different aspects to be envisaged, and showed up inconsistencies of the present concept as well as means and methods for permissible changes and examples of the outcome.

The result of the discussions following these presentations before the Sub-Committee was, that it would not be appropriate at the present time to change the concept, but it was found worthwhile to have a collection and evaluation of all those factors concerning structural safety. As far as possible this collection should include the philosophies which back up the application of these factors and an indication of whether any change is contemplated or not.

The Sub-Committee found it most suitable to collect all pertinent data and back up information by the means of a questionnaire, which has been drafted by two coordinators (one for North America, one for Europe) and reviewed by the members of the Sub-Committee.

This questionnaire is distributed to the addressed Airworthiness Authorities of the NATO-Nations with a request for cooperation. The replies to the questionnaire will be summarized and evaluated by the coordinators for presentation before the Sub-Committee.

Depending on the outcomes of reviewing the collected data the presently applied concept of Factors of Safety may be re-thought.

1.2 How to use the Factors of Safety Questionnaire

1. Please, use separate questionnaire sheets for military and civil aircraft.

2. The responder to the questionnaire is asked to identify the category and type of aircraft he is reporting on and the regulation and/or special certification applied.

   Arm of Service:
   - o Air Force
   - o Army
   - o Navy
   - o Civil Authority

   Military Category:
   - o manned fixed wing aircraft
   - o manned variable geometry aircraft
   - o manned rotary wing aircraft
   - o remotely piloted vehicle
   - o air to air missiles
   - o air to surface missiles
   - o manned research aircraft
   - o space vehicles - manned
     - unmanned

   Civil Category:
   - o normal
   - o utility
   - o aerobatic
   - o transport
   - o normal rotorcraft
   - o transport rotorcraft

Military Specifications	Civil Regulations
o MIL-A-8860 Series	o FAR-Part 23
o AIR 2004/D	o FAR-Part 25
o Av.P. 970	o FAR-Part 27
o MIL-S-8698	o FAR-Part 29
o AR-56	o BCAR, Section X
	o AIR 2052

Please, specify if any other specifications have been/or are applied.

Special Certification

- o Special conditions for an aircraft
- o Particular certification of national authority

e.g. - F-4, Air Force, manned fixed wing a/c, MIL-A-8860
- F28, transport category a/c, FAR-Part 25 and Dutch RLD-document: Airworthiness requirement for type certification of Fokker F28 (March 1967) § 17 (3).

1.3 Factors of Safety Questionnaire

A. Factors of Safety - Structural Aspects

A.1 Where are the required Factors of Safety defined?

- Aircraft Specifications
- Military or Civil Regulations
- Special Certification Documents

please specify if defined otherwise.

A.2 What is the relation of design conditions to the extreme (highest or lowest values) operational conditions?

For example quote load factors, speeds and loads on which the factors are to be applied

- Aircraft with conventional controls
- Aircraft with active controls

A.3 Is the Factor of Safety intended to cover:

- uncertainties in loads?
- inaccuracies in structural analysis?
- deterioration in service?

  - o Do you use Factors of Safety that differ between stress analysis and structural tests on the same item?
- material and production variability? e. g.
  - o allowable value of material strength ("A"- or "B"-values)
  - o factors on castings, forgings, glass, plastics, etc.
  - o allowance for manufacturing tolerances (specified on drawings)

Please, provide a brief narrative answer to each of the points above and provide additional considerations which may be important.

A.4 Do you apply additional factors to cover dynamic effects in lieu of rational analysis? e. g.

- Dynamic Response (gust, ground loads, store ejection, gun firing fuel sloshing, etc.)
- Vibration
- Buffeting
- Stall
- Flutter

In what manner do you use such additional factors?

A.5 Do you apply special Factors of Safety different from those for normal operational conditions to cover rare events? e. g.

- Failure during operation (failure of control system,stability and augmentation devices, engine failure, etc.)
- Emergency landing conditions
- Fail safe conditions (reduced strength due to partial failure)
- Battle damage conditions
- Hammershock, engine surge or compressor stall

Please, provide a brief narrative answer to each of the points above, and identify considerations which may be important, e. g.

definition of the strength depending on the failure probability.

For what other conditons, if any, would a reduced Factor of Safety be used (ground loads, gust loads, etc.)?

A.6 In what way would the aspects of damage tolerance (fatigue, fracture mechanics) influence the Factor of Safety?

A.7 Do you apply different Factors of Safety for the following types of load cases:

- cases where the design load level is defined on the basis of experience, rather than as stated in applicable regulations?
- cases where the aircraft is incapable of producing operational loads in excess of prescribed load levels, or where operational loads are limited by reliable means?

A.8 What is the relationship between operational speed and design speed?

Please, give the cases and the reasons for the applications.

A.9 How do you apply factors for temperature effects? e. g.

- applying an additional factor on the operational value of
  - o the temperature
  - o the temperature rate
  - o the temperature differences
- reducing the strength value of the material depending on the temperature-time-history to be envisaged.

A.10 Do you apply special factors on prototype or experimental vehicles?

If yes, please give value and brief explanation.

A.11 Are special factors applied to the design of the inlet and the engine tie down points?

B. Non-structural Aspects

B.1 Are there other considerations that cover airworthiness and flight safety as a whole that are not involved in Section A?

C. Review and Future Outlook

C.1 Do you believe that the present-day Factors of Safety Concept - as expanded in Section A - is satisfactory?

- If yes, please give a brief explanation.
- If no, what changes would you propose?

C.2 Regarding Factors of Safety, in which area is further theoretical or experimental research - following your own opinion - needed to clarify uncertainties?

C.3 To what extent should we change the present - largely deterministic - approach to a probability approach? e. g.

- loads derived from PSD-methods.
- loads derived from extreme values.

1.4 Letter to the Airworthiness Authorities incl. Distributor

Distributor:
See Attachment 1

Bremen, den 15th Nov. 1978

Concern: AGARD-Structures and Material Panel (SMP)
Sub-Committee SC14/TX.77-Factors of Safety
Questionnaire on Factors of Safety

Reference: Letter by Prof. Dr.-Ing. R.J. Meyer-Jens,
Chairman of SMP-SC 14, dated 11 October 1978

Gentlemen,

with this letter we present to you the Questionnaire on Factors of Safety, which has been prepared by the above mentioned Sub-Committee of AGARD-Structures and Materials Panel in order to get a collection of all those different factors concerning structural safety of aircraft.

The collection should include the numerical values of the factors, the documents on which it is based (regulation etc.) and the way of application.

On behalf of the Sub-Committee we now ask for your kind cooperation in answering as thoroughly as possible the Questionnaire, which consists of three parts:

Part A Factors on structural aspects
Part B Factors on non-structural aspects
Part C Review and future outlook

All Factors of Safety concerning structural aspects which have been applied on present-day aircraft including prototypes are to be described in Part A.

In part B other factors applied covering airworthiness and flight safety should be mentioned.

A review of the present-day Factors of Safety Concept and the possibilities to change the concept is requested in Part C.

We are fully aware of the fact, that it will be difficult in some cases to answer the questions listed in the Questionnaire in short terms.

In such cases it would be helpful to enclose some additional verbal background information and/or by means of papers concerning the special circumstances (conditions).

We would greatly appreciate receiving your answer by the end of February 1979, so that we will be able to give a first presentation of the collected data before the Sub-Committee during the Meeting of SMP in the first week of April 1979.

With many thanks in advance for your willingness to cooperate in this activity and your readiness to write the answer besides your daily workload.

Yours sincerely

(Horst Struck)

Enclosures: - Questionnaire on "Factors of Safety"
- Attachment 1

Attachment 1

Distributor:

1. Belgium:

Major Fournier
Staf van de Luchtmacht
Kwartier Koningin Elisabeth
Everestrat
1140 Bruessel, Belgium

2. Canada:

Brig.Gen. P. Charlton
Director General Aerospace
Engineering and Maintenance
National Defence Headquarters
Ottawa, Ontario K1A OK2
Canada

To be contacted via:

Mr. J. A. Dunsby
Head Structures & Materials Lab.
National Aeronautical Establishment
Ottawa, Ontario
Canada

3. France:

Ingénieur en Chef de l'Armement
Leblanc
Chef de la Section Études Génerales
Service Technique de l'Aêronautique
4, Avenue de la Porte d'Issy
75996 Paris Armees
France

4. Germany:

Dr.-Ing. A. Habel
Bundesamt für Wehrtechnik
und Beschaffung
-Musterprüfstelle für Luftfahrt-
gerät- BWB-ML
Landshuter Allee 162a
8000 München 19
Germany

5. Italy:

F.Col. P. Marconi
Ministero della Difesa
DGCAAAS - 1° Reparto
2° Divisione
Viale Dell' Universitá 4
00185 Roma
Italy

6. Netherlands:

Directie Materieel Koninklijke
Luchtmacht
Prins Claus Laan 8
2595 AJ 's-Gravenhage
Netherlands

Directie Materieel Koninklijke
Marine
Van Speykstraat 52
2518 GD- 's-Gravenhage
Netherlands

7. Norway:

Mr. G. Haakenstad
Royal Norwegian Air Force
Material Command
P.O. Box 10
N-2007 Kjeller
Norway

8. United Kingdom:

Mr. E. L. Ripley
Head Airworthiness Division
Royal Aircraft Establishment
Farnborough, Hants GU 14 6TD
United Kingdom

9. United States:

Air Force Flight Dynamics Laboratory
Attn.: Clement J. Schmid, AFFDL/FBE
Wright-Patterson AFB,
Ohio 45433
USA

Commander

U.S-Army Aviation R&D Command
Attn.: Robert Wolfe, DRDAV-EQA
P.O. Box 209
St. Louis, MO 63166
USA

Naval Air Systems Command
Attn.: E.M. Ryan AIR-510
Washington D.C. 20361

10. Sweden:

Saab-Scania
Aerospace Disiion
Attn.: Dr. Lars Jarfall
Stress R & D, Aircraft Sector
58188 Linköping
Sweden

2. ANSWERS TO THE QUESTIONNAIRE

The answers to the Questionnaire presented in this chapter have been prepared by Horst Struck, coordinator for Europe assisted by Clement J. Schmid, coordinator for North-America. The final version has been reviewed and completed through discussions with the representatives of the authorities and the members of the Sub-Committee.

AUTHORITIES CONCERNED

FRANCE	:	SERVICE TECHNIQUE AERONAUTIQUE (STAE') MR. M. SANCHO
GERMANY	:	BUNDESAMT FUER WEHRTECHNIK (BWB-ML) UND BESCHAFFUNG DR.ING. A. HABEL / MR. M. HACKLINGER
UNITED KINGDOM	:	ROYAL AIRCRAFT ESTABLISHMENT (RAE) MR. P.R. GUYETT
ITALY	:	MINISTERO DELLA DIFESA COL.P. MARCONI
USAF	:	FLIGHT DYNAMICS LABORATORY MR. K.I. COLLIER
US-ARMY	:	AVIATION R & D COMMAND MR. D. SCHRAGE
SWEDEN	:	SAAB - SCANIA, STRESS R & D DR. L. JARFALL

SURVEY TO THE ANSWERS AND THE REVISIONS GIVEN TO THE QUESTIONNAIRE ON FACTORS OF SAFETY

NATION AUTHORITY	REPLY TO QUESTIONS	ANSWERS 1 ST PRESENTATION	REVIEWED ANSWERS 1. ISSUE	2. ISSUE	ACARD R - 677
	TITEL OF PRESENTATION	FIRST EVALUATION	REVIEWED EVALUATION 1. ISSUE	REVIEWED EVALUATION 2. ISSUE	FINAL EVALUATION
FRANCE SERVICE TECHNIQUE AERONAUTIQUE	BY LETTER OF 27.2.79	48TH MTG.	51ST MTG.	NOV. 80	52ND MTG. BY LETTER OF 5.2.81
GERMANY BWB-ML / BUNDESAMT FUER WEHRTECHNIK	BY LETTER OF 20.2.79	48TH MTG.	51ST MTG.	NOV. 80	52ND MTG.
ITALY MINISTERO DELLA DIFESA	BY LETTER OF 27.6.79	49TH MTG.	14.10.80.		BY TELEX 27.4.81
UNITED KINGDOM RAE/ROYAL AIRCRAFT ESTABLISHMENT	BY LETTER OF 05.9.79	49TH MTG.	51ST MTG.	NOV. 80	52ND MTG. BY LETTER OF 14.1.81.
UNITED STATES AIR FORCE	49TH. MTG. 15.10.79	50TH MTG.		51ST MTG.	52ND MTG. BY LETTER OF 15.1.81
UNITED STATES ARMY, HQ AVIATION	BY LETTER OF 13.3.79	49TH MTG.		51ST MTG.	52ND MTG. BY LETTER OF 15.1.81
SWEDEN SAAB - SCANIA AIR FORCE	BY LETTER OF 21.12.79	50TH MTG.		51ST MTG.	52ND MTG. BY LETTER OF 2.2.81

FIRST COMPLETE PRESENTATION OF ANSWERS / FIRST EVALUATION:

First evaluation has been derived from answers given by letter of the authorities.

REVIEWED ANSWERS / REVIEWED EVALUATION:

- 1st issue
  Reviewed and completed through discussions with the representatives of the authorities and the coordinator.

- 2nd issue
  Includes the results and comments of the round table-discussion in the Sub-Committee.

AGARD-R-677 / FINAL EVALUATION:

Revised by comments resulting from circulation of the reviewed evaluation 2nd issue and the summary of the round-table-discussion to the representatives of the authorities and the members of the Sub-Committee.

A. FACTORS OF SAFETY-STRUCTURAL ASPECTS

A.1	**WHERE ARE THE REQUIRED F.O.S. DEFINED ?**
	a) A/C SPECIFICATION
	b) REGULATION
	c) SPECIAL CERTIFICATION DOCUMENTS
	d) OTHERWISE

FRANCE AIR FORCE MANNED FIXED WING A/C	a,c) The regulations and the deviations to be applied for an aircraft are stated in the A/C-Specification. The F.O.S. itself is stated in the regulation.		
	b) - For Mirage 2000 : AIR 20 4/D for ground loads AIR 2004/E for flight loads - For future aircraft: AIR 2004/E will be applied also for ground loads - Civil regulations as FAR 23, 25 may be applied in accordance with the authority.		
GERMANY AIR FORCE/ARMY/NAVY MANNED FIXED/ VARIABLE, GEOMETRY, A/C MANNED ROTARY WING A/C REMOTELY PILOTED VEHICLE	Manned Fixed/Variable Geometry A/C	Manned Rotary Wing A/C	Remotely Piloted Vehicle
	a) A/C Specification	A/C Specification	A/C Specification
	b) MIL-A-8860 series, AIR 2004/D FAR Part 23 25	MIL-A 8860 series MIL-S-8698 AIR 2004/D Av.P.970 FAR Part 27 u. 29 BCAR AIR 2052 SD-24H, vol. II	MIL-A-8860 series with deviation MIL-M-8856 OSTIV Airworthiness Requirements for sailplanes FAR Part 23 with deviations
	c) e.g. Tornado: Air Vehicle Specification (AVS)	Type Specification	Lastenheft
ITALY AIR FORCE MANNED FIXED/ VARIABLE GEOMETRY A/C 1)	a) A/C Specification		
	b) International regulations may be applied when stated in the A/C Specification - MIL-A-8860 series - MIL-S-8698 - AIR 2004/D - Civil regulations		
	c) Any special certification requirements would be stated in the A/C Specification		
	d) Deviation from MIL-Specification, when considered necessary, are qualified and quantified in the A/C Specification.		

1) For Manned Rotary Wing A/C the same criteria will be applied as for Fixed Wing A/C.

continued

A. FACTORS OF SAFETY-STRUCTURAL ASPECTS

A.1	WHERE ARE THE REQUIRED F.O.S. DEFINED ?
	a) A/C SPECIFICATION
	b) REGULATION
	c) SPECIAL CERTIFICATION DOCUMENTS
	d) OTHERWISE

UNITED KINGDOM AIR FORCE/ ARMY/ NAVY ALL AIRCRAFT/ ROTORCRAFT	a) A/C Specification
	b) Design Requirements: Av.P.970 and associated memoranda
	c) Any special certification requirements would be stated in the A/C Specification.
	d) Military variants of civil aircraft are normally accepted to civil requirements.
UNITED STATES AIR FORCE MANNED FIXED / VARIABLE GEOMETRY A/C	a) Aircraft Specifications reflect F.O.S. from regulations (USAF Military Specifications).
	b) For USAF developed aircraft, the F.O.S. are defined in the MIL-A-008860(USAF) series specifications (regulations). The F.O.S. are defined by other agency regulations for aircraft used by the USAF but developed under the auspices of other agencies, e.g., transports and light aircraft applicable F.O.S. are in accordance with FAR Part 25 and FAR Part 23.
	c) N/A.
	d) N/A.
UNITED STATES ARMY MANNED ROTARY WING A/C MANNED FIXED WING TRANSPORT A/C	a) System Specification (SS)
	b) Prime Item Development Specification (PIDS) derived from : MIL-S-8690 MIL-A-008870 MIL-T-5955 AVRADCOM ADS -13
	d) Airworthiness Qualification Specification (AQS) derived from : AMCP 706-203 and MIL-T-8679
SWEDEN, SAAB-SCANIA AIR FORCE MANNED FIXED WING A/C	a) Military Design Requirements

A. FACTORS OF SAFETY-STRUCTURAL ASPECTS

A.2	WHAT IS THE RELATION OF DESIGN CONDITIONS TO THE EXTREME OPERATIONAL CONDITIONS?
FRANCE AIR FORCE MANNED FIXED WING A/C	The limit conditions correspond to the maximum operating conditions. There is no margin specified in the regulation but the operational envelope as stated in the manual of the aircraft has to be covered by the design envelope. No additional requirements for aircraft with active controls are in the regulation. As yet the existing requirements are considered to be adequate.
GERMANY AIR FORCE/NAVY MANNED FIXED/ VARIABLE,GEOMETRY,A/C	In general none Loads: In special cases where AIR 2004/D Regulation is relevant. Pressurization: According to Regulation : . MIL-A-008861A . AIR 2004/D There is no different application between conventional aircraft and aircraft with active controls.
ITALY AIR FORCE MANNED FIXED/ VARIABLE GEOMETRY A/C	The structural design conditions cover the operational flight envelope as defined by MIL-F-8785. When exceeding in service the flight envelope limits, the same MIL-Specification gives some guidance to define checks to be performed on the A/C. For A/C with active controls as yet no additional requirements are defined.
UNITED KINGDOM AIR FORCE/ ARMY/ NAVY ALL AIRCRAFT/ ROTORCRAFT	Static Design loads (to which the design Proof and Ultimate factors - usually 1.125 and 1.50 - are applied) are those which are expected to occur only rarely. The associated temperatures and (for composites) moisture uptakes are those most likely to prevail when the design loads are applied. Fatigue Design loads are normally those most likely to be experienced under the specified operating conditions. More severe design conditions are used when the service usage is unmonitored. As yet there are no additional requirements for aircraft with active controls. The existing requirements are considered to be adequate, in principle, provided care is taken to ensure that all the loading actions are known and understood.

continued

A. FACTORS OF SAFETY-STRUCTURAL ASPECTS

A.2	WHAT IS THE RELATION OF DESIGN CONDITIONS TO THE EXTREME OPERATIONAL CONDITIONS?
UNITED STATES AIR FORCE MANNED FIXED / VARIABLE GEOMETRY A/C	Limit load design conditions could be exceeded during mission and pilot induced extreme operational conditions. Regarding environmental design conditions, the extremes, such as large hail stones, thunderstorms, etc., are not normally used for USAF aircraft design purposes. Some lesser values have been used for aircraft design purposes, since extreme conditions are avoided if possible. No additional requirements for aircraft with active controls are in the regulation. As yet the existing requirements are considered to be adequate.
UNITED STATES ARMY MANNED ROTARY WING A/C MANNED FIXED WING TRANSPORT A/C	Extreme operational load factors and speeds are estimated to be within 5% to 15% of the design conditions.
SWEDEN, SAAB-SCANIA AIR FORCE MANNED FIXED WING A/C	Limit load factor does occur and is occasionally exceeded. Speed limits are chosen such that the probability of their exceedance is low. In part of the flight envelope, roll rate is limited by autopilot action and loads determined with these limited roll rates. If the autopilot fails the pilot gets a warning and has to apply restrictions. (In all cases mentioned above the normal F.O.S.=1.5 is applied to expected loads). In general fatigue design load spectra are expected to be exceeded by 2% of the fleet.

A. FACTORS OF SAFETY - STRUCTURAL ASPECTS

A.3	IS THE F.O.S. INTENDED TO COVER:
	a) 1. OPERATIONAL EXCEEDANCES OF DESIGN CONDITIONS 2. UNCERTAINTIES IN LOADS
	b) INACCURACIES IN STRUCTURAL ANALYSIS
	c) DETERIORATION IN SERVICE
	d) MATERIAL AND PRODUCTION VARIABILITY?
	e) SPECIAL FACTORS/ADDITIONAL FACTORS

FRANCE AIR FORCE MANNED FIXED WING A/C	The purpose of the F.O.S. is to give safety against the uncertainties of all four points (a to d) as a whole. it seems not to be realistic to split up the F.O.S. into separate factors, because from the statistical point of view it is not conceivable for the most critical cases to occur at the same time. a) Yes, including the accidental exeedance of the normal operational conditions.
	b) Yes, after completion of static tests up to ultimate load and beyond, there will be less uncertainties as in structural analysis, e.g. those inaccuracies that result from the difference between test structure and service aircraft.
	c) Yes
	d) Yes
	e) Factors are applied for: - castings - forgings - composite materials - glass, plastics - fittings
GERMANY AIR FORCE/NAVY MANNED FIXED/ VARIABLE,GEOMETRY,A/C	a) 1. Yes 2. -Yes, if complicated load case. for example: transonic flow, elastic structure etc. -No, if simple load case. for example: unsymmetrical pull up, subsonic flow, rigid structure
	b) Analysis : Yes Test : No, after completion of compliance tests.
	c) Random deterioration is covered but see e)
	d) Material: No, covered by allowable design values (A-,B-values) Production: Yes
	e) Factors on - castings - forgings - glass, plastics - fittings - fiber composites in general

A. FACTORS OF SAFETY-STRUCTURAL ASPECTS

<table>
<tr><td rowspan="6">A.3</td><td colspan="2">IS THE F.O.S. INTENDED TO COVER:</td></tr>
<tr><td colspan="2">a) 1. OPERATIONAL EXCEEDANCES OF DESIGN CONDITIONS
2. UNCERTAINTIES IN LOADS</td></tr>
<tr><td colspan="2">b) INACCURACIES IN STRUCTURAL ANALYSIS</td></tr>
<tr><td colspan="2">c) DETERIORATION IN SERVICE</td></tr>
<tr><td colspan="2">d) MATERIAL AND PRODUCTION VARIABILITY?</td></tr>
<tr><td colspan="2">e) SPECIAL FACTORS/ADDITIONAL FACTORS</td></tr>
<tr><td colspan="2" rowspan="5">ITALY
AIR FORCE
MANNED FIXED/
VARIABLE GEOMETRY A/C</td><td>a) 1. - No, if resulting from pilot handling (in general it should be covered by flight testing and experiences).
-Yes, if deriving from A/C Systems.
2. Yes</td></tr>
<tr><td>b) Yes</td></tr>
<tr><td>c) No, this problem is covered by adequate in service inspections and by proper protective treatements.</td></tr>
<tr><td>d) Material : No, but additional factors are to be used (→e)
Production: Yes</td></tr>
<tr><td>e) Factors are used for :
- castings
- fittings (in absence of adequate static test)
- composites and plastics
- forgings</td></tr>
<tr><td colspan="2" rowspan="5">UNITED KINGDOM
AIR FORCE/ ARMY/ NAVY
ALL AIRCRAFT/
ROTORCRAFT</td><td>a) 1. For the flying in service, it is now usual practice to define never-exceed limits of operation for aircrew. These would normally correspond to the design levels (limit load conditions). It is the general requirement that these limits should be observed strictly. The F.O.S. does, however, provide some safeguard if there is any flying outside the defined limits.

2.Yes, but small uncertainties only should remain after the completion of the development programme that usually includes analysis, wind-tunnel tests and flight load measurements, supplemented in service by operational load assessment using a counting accelerometer (Fatique Meter), and, in some cases, by detailed load measurement.</td></tr>
<tr><td>b) Yes, to cover those inaccuracies that remain after compliance procedure which, on major components would include a strain survey and extensive structural tests.</td></tr>
<tr><td>c) No allowance for deterioration due to corrosion made in the process of design or tests (reliance placed on protective treatment) and hence F.O.S provides a measure of allowance for such deterioration occuring in service.</td></tr>
<tr><td>d) Materials : No, material variability should be covered by "A","B","specification" values.
Production: Yes,the F.O.S. provides some safeguard against shortfalls in manufacturing, related design and inspection processes.</td></tr>
<tr><td>e) Orthodox Materials: Special factors are used in design for some materials such as forgings, castings and transparences. These factors are reduced as more specimens are tested.
Composite Materials: In design no special factor is applied since reliance is placed on "A"- and "B"-values. The test factor must be sufficiently high to reveal unforeseen critical features or failure modes.</td></tr>
</table>

A. FACTORS OF SAFETY-STRUCTURAL ASPECTS

A.3	IS THE F.O.S. INTENDED TO COVER:
	a) 1. OPERATIONAL EXCEEDANCES OF DESIGN CONDITIONS 2. UNCERTAINTIES IN LOADS
	b) INACCURACIES IN STRUCTURAL ANALYSIS
	c) DETERIORATION IN SERVICE
	d) MATERIAL AND PRODUCTION VARIABILITY?
	e) SPECIAL FACTORS/ADDITIONAL FACTORS

UNITED STATES AIR FORCE MANNED FIXED / VARIABLE GEOMETRY A/C	a) Uncertainties and inaccuracies in basic loads are expected to be uncovered and corrected during the development program. The F.O.S. are expected to cover those uncertainties and inadvertent load exceedances which may exist or occur after development.
	b) Any fundamental inaccuracies of the stress analysis are expected to be uncovered and corrected during the development program, particularly during ground tests of the aircraft structure. Effects of basing the analysis on nominal dimensions, not extreme tolerances, other assumptions and inaccuracies which exist after development are expected to be covered by the F.O.S.
	c) Durability and damage tolerant flight safety critical components are not covered by F.O.S. regarding service induced deterioration. However, regarding strength critical parts, the F.O.S. provides a necessary margin to allow for detection and repair of service deterioration and to enhance the confidence in the structural integrity of the airframe.
	d) Material variability is covered by "A" and "B" values specified in approved material handbooks. However, the production variability existing after construction which adheres to the high quality standards of aerospace industry workmanship is expected to be covered by the F.O.S.
	e) Other special and additional factors may be specified, for example, casting factors, fitting factors, pressurized structure, etc.
UNITED STATES ARMY MANNED ROTARY WING A/C MANNED FIXED WING TRANSPORT A/C	There must be no yielding at limit load and no failure at ultimate load. a) Yes
	b) Yes
	c) No, there is no direct F.O.S. applied to account for deterioration.
	d) The stuctural analysis must be performed using the nominal gages for sheet metal and the average thickness between tolerances. Special attention is given to adverse tolerances and when considered necessary, minimum dimensions are used.
	e) "A"-values are used for all statically determinate structures. "B"-values are used for all crash conditions, and structure, the failure of which would have no safety-of-flight implications (floor loading). B-values also used on fail-safe redundant structures. Factors on - castings (class I) → MIL-C-6021 G unless procured → MIL-A-21180 C casting factor = 1.25, ultimate load = 1.25 * 1.5 * limit load In lieu of an analytical factor of 1.25 the casting may be substantiated by static tests.

A. FACTORS OF SAFETY-STRUCTURAL ASPECTS

A.3	**IS THE F.O.S. INTENDED TO COVER:**
	a) 1. OPERATIONAL EXCEEDANCES OF DESIGN CONDITIONS **2. UNCERTAINTIES IN LOADS**
	b) INACCURACIES IN STRUCTURAL ANALYSIS
	c) DETERIORATION IN SERVICE
	d) MATERIAL AND PRODUCTION VARIABILITY?
	e) SPECIAL FACTORS/ADDITIONAL FACTORS

SWEDEN, SAAB-SCANIA AIR FORCE MANNED FIXED WING A/C	a) To a large extent
	b) To a very limited extent (uncertainties are mainly covered by tests)
	c) To a limited extent (deterioration is expected to be found and repaired at an early stage)
	d) - Hardly any material variability as A-values for material strength are applied and reduced allowable values are used for materials with large scatter in strength e.g. castings, glass, plastics. Morever the extent of quality control of forgings, castings and adhesive bonds is tied to whether the parts are vital, important or secondary. Test results are corrected by taking material specimen as near to the rupture as possible and determining material properties, after which the test result is corrected to minimum allowable material poperties. - no size tolerances as single load carrying members are, in stress analysis, assumed to be of minimum size. On single A/C, however, a reduction of 10% in strength due to manufacturing tolerances is allowed and considered to be covered by the normal F.O.S.
	e) The following extra factors are applied as a general precaution against maintenance damage, buffeting and load uncertainties: (Extra factor:) - Joint to be disassembled for inspection in wing and fuselage, engine mountings etc. — 1.15 - control surface brackets — 1.15 - bearings and servos for control surfaces, flaps, air brakes and ram air turbine (air loads only) — 1.38 - fixed bolted riveted joints in integral tanks with sealing compound between parts — 1.25 - compressed air system — 1.3 - pressure vessels (1.6 against yielding) — 1.33 - flexible tubing — 2.0 - calculated air loads — 1.2

A. FACTORS OF SAFETY-STRUCTURAL ASPECTS

A.4	DO YOU APPLY ADDITIONAL FACTORS TO COVER DYNAMIC EFFECTS IN LIEU OF RATIONAL ANALYSIS? a) GENERAL b) SPECIAL CASES
FRANCE AIR FORCE MANNED FIXED WINGA/C	a) No, generally the Norm requires the dynamic effects to be taken into account. Concerning estimation methods, no additional factor is applied, because the assumption will be considered as conservative. b) In particular cases a dynamic factor is included in the formula giving the limit load which is to replace the rational analysis e.g. estimation of ground loads.
GERMANY AIR FORCE/NAVY MANNED FIXED/ VARIABLE,GEOMETRY,A/C	a) No. b) Yes, in special cases - dynamic overswing for external stores - ground loads due to dynamic - spin up - spring back until completion of rational analysis or relevant tests.
ITALY AIR FORCE MANNED FIXED/ VARIABLE GEOMETRY A/C	a) Not in general: The analysis must cover the effect of dynamic response. b) Special cases are missile firing, gunfire vibration, dynamic overswing of external stores. This special factor based on past experience is applied when the loads derived from the rational analysis cannot give sufficient confidence.
UNITED KINGDOM AIR FORCE/ ARMY/ NAVY ALL AIRCRAFT/ ROTORCRAFT	a) No, dynamic effects are usually determined by analysis and/ or testing, although acceptable methods of calculating gust loads and undercarriage loads by special factors are available. b) Exceptionally, e.g. a proof factor of 1.3 on ejection seat mountings.
UNITED STATES AIR FORCE MANNED FIXED / VARIABLE GEOMETRY A/C	a) No. b) Prefer rational analysis. However, additional factors based on past experience are used for those cases which cannot be rationally analyzed with confidence. Such cases include aerodynamically induced oscillatory loads or buffet, etc., and dynamic magnification factor for load redistributions at time of failure of a component in fail safe structure.
UNITED STATES ARMY MANNED ROTARY WING A/C MANNED FIXED WING TRANSPORT A/C	a) Additional factors are used in lieu of rational analysis b) - aeroelasticity: a 1.15 factor is applied to the design limit flight speed/rotor speed - torque : a factor (1.5 rotor acceleration, 2.0 rotor braking) is applied to the main transmission, engine mounts, etc. simultaneously with flight load factor for power-on conditions only. - crash load : for large mass items steady state load factors have been defined - drive system : overspeed tests are utilized to account for dynamic effects. (transmissions to 110%, fans/shaft driven compressors to 135%, engines to 116% of normal operating speed.)
SWEDEN, SAAB-SCANIA AIR FORCE MANNED FIXED WING A/C	For installed equipment with $W < 40$kg an extra factor 1.67 is applied to cover dynamic effects. For weights $40 < W < 150$kg the factor is log-linearly reduced to 1. All other dynamic effects are covered by rational analysis.

A. FACTORS OF SAFETY-STRUCTURAL ASPECTS

A.5	DO YOU APPLY SPECIAL F.O.S. DIFFERENT FROM THOSE FOR NORMAL OPERATIONAL CONDITIONS? a) FAILURE DURING OPERATION b) EMERGENCY LANDING CONDITION c) FAIL SAFE CONDITIONS d) BATTLE DAMAGE CONDITIONS e) HAMMERSHOCK, ENGINE SURGE, COMPRESSOR STALL f) STRUCTURAL DAMAGE AS A RESULT OF .BIRD IMPACT / .DISC BURST
FRANCE AIR FORCE MANNED FIXED WING A/C	a) The Norm allows to apply a lower F.O.S. depending on the probability of the failure ,which is to be agreed with the authority. b) The regulation gives the values of the inertial load factor due to crash as ultimate loads. c) Limit loads are to be applied , F.O.S. is 1.0 . d) Not yet considered e) No f) No, reference to US-AIR FORCE
GERMANY AIR FORCE/NAVY MANNED FIXED/ VARIABLE GEOMETRY A/C	a) In general no b) Crash landing load factors are applied, according to MIL-A-008865. c) 80% of the design ultimate loads are applied. d) In discussion e) No, reference to US-AIR FORCE f) No
ITALY AIR FORCE MANNED FIXED/ VARIABLE GEOMETRY A/C	a) No, only the effect on flight quality levels are considered. (MIL-F-8785) b) Crash landing factors are applied following regulation. c) Not yet. d) The application of special F.O.S. is under discussion e) No f) Not to be covered by F.O.S.

continued

A. FACTORS OF SAFETY - STRUCTURAL ASPECTS

A.5	DO YOU APPLY SPECIAL F.O.S. DIFFERENT FROM THOSE FOR NORMAL OPERATIONAL CONDITIONS?
	a) FAILURE DURING OPERATION
	b) EMERGENCY LANDING CONDITION
	c) FAIL SAFE CONDITIONS
	d) BATTLE DAMAGE CONDITIONS
	e) HAMMERSHOCK, ENGINE SURGE, COMPRESSUR STALL
	f) STRUCTURAL DAMAGE AS A RESULT OF .BIRD IMPACT / .DISC BURST

UNITED STATES AIR FORCE MANNED FIXED / VARIABLE GEOMETRY A/C	a) Normally no special factors are used for failures during operation such as control systems, SAS, engine, etc. These conditions are defined and accounted for in the design criteria.
	b) No special factors are specified for landing conditions after declared in-flight emergencies. If the "emergency landing condition" is meant to include crashes, the F.O.S. concept is not applied and the specified loads and factors are used directly to determine ultimate values.
	c) Residual strength requirements and factors, replacing the normal F.O.S. are defined in the military regulations.
	d) Residual strength requirements are tailored to the particular weapon system under development.
	e) Special factors are normally not applied for these conditions and development efforts are expected to uncover and correct any unsatisfactory conditions which may arise.
	f) - Bird inpact: Normally considered an ultimate load condition requiring only survival of personnel and recovery of the aircraft. - Disk burst : Normally considered an ultimate containment condition requiring no injury to personnel and recovery of the aircraft.
UNITED STATES ARMY MANNED ROTARY WING A/C MANNED FIXED WING TRANSPORT A/C	a) In general special F.O.S. are not used. When major structural components are failed or damaged, it is considered an ultimate condition (i.e., F.O.S. is 1.0)
	b) Crash: quasi static load factors are defined for the design of the support structure for large mass items which might pose a hazard to the crew. All crash conditions are ultimate and the F.O.S. is 1.0.
	c) A fail safe assembly is required by definition to carry limit load without failure with at least one major load path severed. Fail safe is an ultimate consideration and the F.O.S. is 1.0.
	d) The aircraft is required to fly a reduced flight spectrum for 30 minutes and land safely subsequent to receiving battle damage from a specified ballistic projectile. This is an ultimate condition and the F.O.S. is 1.0.
	f) When major structural components are failed or damaged it is considered as ultimate condition i.e. the F.O.S. is 1.0

Remark: The sequence of the Nations have been altered exceptionally for the answers to this question with respect to printing conditions.

A. FACTORS OF SAFETY-STRUCTURAL ASPECTS

A.5	DO YOU APPLY SPECIAL F.O.S. DIFFERENT FROM THOSE FOR NORMAL OPERATIONAL CONDITIONS? a) FAILURE DURING OPERATION b) EMERGENCY LANDING CONDITION c) FAIL SAFE CONDITIONS d) BATTLE DAMAGE CONDITIONS e) HAMMERSHOCK, ENGINE SURGE, COMPRESSOR STALL f) STRUCTURAL DAMAGE AS A RESULT OF .BIRD IMPACT / .DISC BURST	
UNITED KINGDOM AIR FORCE/ ARMY/ NAVY ALL AIRCRAFT/ ROTORCRAFT		a) In general failures of control system, engine etc. are covered by design philosophy (e.g. multi-plex circuits) rather than by factors. In some circumstances where the probability is very remote a concession might be negotiated. b) Yes, seats and other critical items are designed to withstand crash landing accelerations with an ultimate factor of 1.0. c) Yes, the residual strength must not decrease below 80% of the design ultimate strength before replacement or repair is made. d) No e) No f) - Bird impact: any quantitative requirement is stated in the individual aircraft specification, and usually calls for performance to be demonstrated by test at an ultimate load factor of 1.0. - Disk burst : the general engine design requirements state that the outer casings of the engine or supplementary containment shields shall be of sufficient strenght to prevent the escape of any compressor or turbine <u>blades</u> which may disintegrate or become detached: the ultimate load factor is thus 1.0. <u>Disk</u> burst is not covered by the requirements.
SWEDEN, SAAB-SCANIA AIR FORCE MANNED FIXED WING A/C		The following rare events are covered by safety factors lower than the normal value of 1.5 F.O.S. b) crash landing — 1.0 f) no risk for serious injury of pilot - carrier type landing (where a low probability vertical velocity is selected) — 1.15 - ejection seat — 1.15 - mechanical seizing of servos (load based on 1.2 times normal hydraulic pressure) — 1.05

A. FACTORS OF SAFETY-STRUCTURAL ASPECTS

A.6	IN WHAT WAY WOULD THE ASPECTS OF DAMAGE TOLERANCE INFLUENCE THE F.O.S. ?
FRANCE AIR FORCE MANNED FIXED WINGA/C	No influence
GERMANY AIR FORCE/NAVY MANNED FIXED/ VARIABLE,GEOMETRY,A/C	The application of damage tolerance design principles does not directly influence the F.O.S. For the residual strenght requirements specifications such as MIL-A-83444 are being applied.
ITALY AIR FORCE MANNED FIXED/ VARIABLE GEOMETRY A/C	Damage tolerance criteria are based on a different design philosophy therefore the F.O.S. is not directly affected.
UNITED KINGDOM AIR FORCE/ ARMY/ NAVY ALL AIRCRAFT/ ROTORCRAFT	New requirements are being drafted. These will maintain at least the levels of safety associated with the present safe life and fail safe design requirements. Higher effective F.O.S. will result if no cracks are present; the minimum F.O.S. will be the value of 1.2 stated in the fail safe requirement.
UNITED STATES AIR FORCE MANNED FIXED / VARIABLE GEOMETRY A/C	None. However, the use of damage tolerance and fracture mechanics concepts tend to lower stress levels in the airframe. Some structural components therefore tend to have a higher effective F.O.S. initially. All safety-of-flight structure must comply with the residual strength requirements of military regulations.
UNITED STATES ARMY MANNED ROTARY WING A/C MANNED FIXED WING TRANSPORT A/C	All safety-of-flight structure must comply with the residual strength requirements of military regulations.
SWEDEN, SAAB-SCANIA AIR FORCE MANNED FIXED WING A/C	Damage tolerance is treated as a separate design condition.

A. FACTORS OF SAFETY-STRUCTURAL ASPECTS

A.7	DO YOU APPLY DIFFERENT F.O.S FOR FOLLOWING TYPES OF LOAD CASES : a) DESIGN LOAD LEVEL IS STATED IN REGULATIONS b) OPERATIONAL LOADS ARE LIMITED
FRANCE AIR FORCE MANNED FIXED WINGA/C	Not generally, but for A/C with particular characteristics, design conditions different from the Norm might be determined.
GERMANY AIR FORCE/NAVY MANNED FIXED/ VARIABLE,GEOMETRY,A/C	Normally no, but if in special case it can be proven that 1.5 limit load physically is not achievable (e.g. limiting device) a lower F.O.S. can be accepted.
ITALY AIR FORCE MANNED FIXED/ VARIABLE GEOMETRY A/C	No
UNITED KINGDOM AIR FORCE/ ARMY/ NAVY ALL AIRCRAFT/ ROTORCRAFT	a) Design load level as stated in the A/C Specification is based on experience and so no distinction is made between "experience" and "regulations". b) Not in general, but cases are considered on their merits.
UNITED STATES AIR FORCE MANNED FIXED / VARIABLE GEOMETRY A/C	a) Normally, no. However there are selected conditions where in regulation specified loads and factors are ultimate values and the normal F.O.S. are not applied. b) No, normally handled in the usual manner regardless of the difficulty in achieving or exceeding the limit design loads.
UNITED STATES ARMY MANNED ROTARY WING A/C MANNED FIXED WING TRANSPORT A/C	Reduced F.O.S. are not defined for the following reasons: - U.S. Army aircraft operate close to the design boundary with a small margin between design and operational usage. - It is Army's experience that growth potential is required over the life time of an aircraft system (new mission profiles, improved weaponry, heavier payloads, improved engines).
SWEDEN, SAAB-SCANIA AIR FORCE MANNED FIXED WING A/C	No different F.O.S. are applied.

A. FACTORS OF SAFETY-STRUCTURAL ASPECTS

A.8	WHAT IS THE RELATIONSHIP BETWEEN OPERATIONAL SPEED AND DESIGN SPEED ?
FRANCE AIR FORCE MANNED FIXED WINGA/C	No factors given in the Norm. The user cnoose a margin in comparison with the design envelope.
GERMANY AIR FORCE/NAVY MANNED FIXED/ VARIABLE,GEOMETRY,A/C	In general maximum operational speed < design speed. e.g. operational speeds for flap extension are 20 - 30 kts less than design speeds.
ITALY AIR FORCE MANNED FIXED/ VARIABLE GEOMETRY A/C	The Norms do not give any factor therefore each factor is to be tailored to individual aircraft type and to the related flight envelope. However the max. operational speed is in general less than the max. design advice speed. The AIR 2004/D gives some advice to get through the mentioned exercise. (This is a comment not to be included in the Norm)
UNITED KINGDOM AIR FORCE/ ARMY/ NAVY ALL AIRCRAFT/ ROTORCRAFT	A Limiting Speed is choser so that the design speed will not be exceeded. Typically for subsonic aeroplanes the Limiting Speed is 10% below the design speed. In some cases a never exceed speed is stated. A similar approach is followed for rotorcraft.
UNITED STATES AIR FORCE MANNED FIXED / VARIABLE GEOMETRY A/C	The relationship is dependent upon the type of aircraft, the operational requirements and the military regulations. Normally the design speed is greater than the operational speed to allow for infrequent overshoots of shallow dives, gust upsets, short time transient excursions required by some missions, et cetera.
UNITED STATES ARMY MANNED ROTARY WING A/C MANNED FIXED WING TRANSPORT A/C	The relationships are as follows: a) Forward airspeed - structural : no difference - aeroelastic: a factor of 1.15 (MIL-A-008870) b) Rotor speed - structural : a factor of 1.25 (MIL-S-8698 and MIL-T-8679) - aeroelastic: an additional factor of 1.15 is added to the structural consideration (AR-56 and MIL-A-008870)
SWEDEN, SAAB-SCANIA AIR FORCE MANNED FIXED WING A/C	Design speeds are chosen such that their exceedance is improbable.

A. FACTORS OF SAFETY-STRUCTURAL ASPECTS

A.9	HOW DO YOU APPLY FACTORS FOR TEMPERATURE EFFECTS?
FRANCE AIR FORCE MANNED FIXED WINGA/C	The allowable mechanical values of materials are reduced and the stress level resulting from temperature is calculated by a reduced factor . (1.25)
GERMANY AIR FORCE/NAVY MANNED FIXED/ VARIABLE,GEOMETRY,A/C	Analysis: The allowable strength values of materials are reduced according to the temperatures reached in service. The resulting stresses are multiplied by the usual F.O.S. Test : Qualification tests will be done under the most critical temperature conditions.(e.g. for advanced composites)
ITALY AIR FORCE MANNED FIXED/ VARIABLE GEOMETRY A/C	The allowable strength values of materials are reduced according to the temperatures reached in service and the thermal stresses are considered. The resulting stresses are multiplied by the usual F.O.S.
UNITED KINGDOM AIR FORCE/ ARMY/ NAVY ALL AIRCRAFT/ ROTORCRAFT	In general, the virtual strain in a member due to thermal effects is multiplied by the usual proof and load factors; it is then combined with the factored strain due to the externally applied loads, determined assuming no thermal strains are acting. The associated stress is found for this combined strain from the stress-strain curve for the member. Material properties and allowable strength values are taken at the aircraft design temperatures.
UNITED STATES AIR FORCE MANNED FIXED / VARIABLE GEOMETRY A/C	Temperature effects on structures are accomplisned by reducing the room temperature strength values in accordance with approved handbooks and other sources.
UNITED STATES ARMY MANNED ROTARY WING A/C MANNED FIXED WING TRANSPORT A/C	Temperature effects are covered by reducing the strength value of the material based on MIL-HDBK-5, or other approved sources.
SWEDEN, SAAB-SCANIA AIR FORCE MANNED FIXED WING A/C	Temperature effects are accounted for by a reduction in the strength value of the material.

A. FACTORS OF SAFETY-STRUCTURAL ASPECTS

A.10	DO YOU APPLY SPECIAL FACTORS ON PROTOTYPE OR EXPERIMENTAL VEHICLES ?
FRANCE **AIR FORCE** **MANNED FIXED WINGA/C**	No
GERMANY **AIR FORCE/NAVY** **MANNED FIXED/** **VARIABLE,GEOMETRY,A/C**	Prototypes : - No, if the normal strength programme is conducted. - Yes, if only analytical proof is provided. Experimental: A special additional factor may be applied.
ITALY **AIR FORCE** **MANNED FIXED/** **VARIABLE GEOMETRY A/C**	No
UNITED KINGDOM **AIR FORCE/ ARMY/ NAVY** **ALL AIRCRAFT/** **ROTORCRAFT**	Not if an adequate test programme is followed. If a test programme is not planned and reliance placed on calculation additional factors are applied.
UNITED STATES **AIR FORCE** **MANNED FIXED /** **VARIABLE GEOMETRY A/C**	Normally, yes, since additional analytical strength is more cost effective and timely than required flight and ground tests necessary to verify the airframe for the usually limited usage.
UNITED STATES **ARMY** **MANNED ROTARY WING A/C** **MANNED FIXED WING** **TRANSPORT A/C**	Special factors may be applied to prototype A/C e.g. a special reduction factor will be applied to the mean S-N-curve of a fatigue critical component if the required number of specimens have not been tested prior to flight.
SWEDEN, SAAB-SCANIA **AIR FORCE** **MANNED FIXED WING A/C**	Normal factors of safety are applied to prototypes except that the reduction of strength of 10% due to manufacturing tolerances, as mentioned under A.3, may be increased to 16%.

A. FACTORS OF SAFETY-STRUCTURAL ASPECTS

A.11	ARE SPECIAL FACTORS APPLIED TO THE DESIGN OF THE INLET AND THE ENGINE TIE DOWN POINTS ?
FRANCE AIR FORCE MANNED FIXED WINGA/C	No
GERMANY AIR FORCE/NAVY MANNED FIXED/ VARIABLE,GEOMETRY,A/C	No
ITALY AIR FORCE MANNED FIXED/ VARIABLE GEOMETRY A/C	No
UNITED KINGDOM AIR FORCE/ ARMY/ NAVY ALL AIRCRAFT/ ROTORCRAFT	No
UNITED STATES AIR FORCE MANNED FIXED / VARIABLE GEOMETRY A/C	Normally, no, relying on the development program to uncover and correct any abnormalities.
UNITED STATES ARMY MANNED ROTARY WING A/C MANNED FIXED WING TRANSPORT A/C	Special factors are not applied to the design of engine inlet or the tie down points.
SWEDEN, SAAB-SCANIA AIR FORCE MANNED FIXED WING A/C	No special factors are applied to the air intake. Engine mounting extra factor is 1.15 (sec. A.3).

B. NON-STRUCTURAL ASPECTS

B	ARE THERE OTHER CONSIDERATIONS THAT COVER FLIGHT SAFETY AND AIRWORTHINESS AS A WHOLE?
FRANCE **AIR FORCE** **MANNED FIXED WINGA/C**	No comment
GERMANY **AIR FORCE/ARMY/NAVY** **MANNED FIXED/** **VARIABLE,GEOMETRY,A/C**	Yes, e. g. - endurance/confidence tests on system rigs - safety analyses - reliability analyses/demonstrations - acoustic noise (Manned Rotary Wing A/C)
ITALY **AIR FORCE** **MANNED FIXED/** **VARIABLE GEOMETRY A/C**	No comment
UNITED KINGDOM **AIR FORCE/ ARMY/ NAVY** **ALL AIRCRAFT/** **ROTORCRAFT**	Yes, these relate to items such as security of fixing of doors and panels, protection against lightning strike, protection from icing, protection from exhaust gases from weapons and positioning of turbine discs to minimise damage in the event of noncontainment.
UNITED STATES **AIR FORCE** **MANNED FIXED /** **VARIABLE GEOMETRY A/C**	In general, yes. Interfaces with all of the other technical disciplines and operational requirements influence the flight safety and airworthiness of the air vehicle as a whole. Such disciplines include aerodynamics and performance, safety (including nuclear safety), vehicle systems (including control, avionics, fuel. etc.), cost effectiveness of the various production techniques, maintenance efforts and costs, and others. Each interface must be evaluated and integrated on its own relative merits.
UNITED STATES **ARMY** **MANNED ROTARY WING A/C** **MANNED FIXED WING** **TRANSPORT A/C**	Inherent F.O.S. will exist in certain components based on environmental testing versus operational usage. e.g. - the accelerated life-testing of elastomeric bearings - vibration testing of IR suppressor - endurance testing of engine and drive system components
SWEDEN, SAAB-SCANIA **AIR FORCE** **MANNED FIXED WING A/C**	No comment

C. REVIEW AND FUTURE OUTLOOK

C.1	DO YOU BELIEVE THAT THE PRESENT-DAY F.O.S.-CONCEPT IS SATISFACTORY ?
FRANCE AIR FORCE MANNED FIXED WINGA/C	Up to now for a fighter A/C the present concept and the values of the F.O.S. seems to be realistic. For composite components additional factors might be used to cover the influence of environmental degradation and manufacturing variability.
GERMANY AIR FORCE/ARMY/NAVY MANNED FIXED/ VARIABLE,GEOMETRY,A/C	For metal parts yes, but for composite parts additional factors must be used to cover the influence of environmental degradation due to temperature, moisture, UV-light, manufacturing variability etc.
ITALY AIR FORCE MANNED FIXED/ VARIABLE GEOMETRY A/C	F.O.S. adopted nowadays for Military Aircraft metal alloy structures are satisfactory, but they could be revised following state of art improvements.
UNITED KINGDOM AIR FORCE/ ARMY/ NAVY ALL AIRCRAFT/ ROTORCRAFT	Yes, but we believe that an international rationalization of factors is timely to achieve more uniform standards of safety and, possibly, increased operational effectiveness.
UNITED STATES AIR FORCE MANNED FIXED / VARIABLE GEOMETRY A/C	The present-day F.O.S. concept is satisfactory when complemented with an effective durability and damage tolerance program. These disciplines are in existence today only because the F.O.S. concept cannot and was not intended to accommodate or account for high intensity cyclic loadings.
UNITED STATES ARMY MANNED ROTARY WING A/C MANNED FIXED WING TRANSPORT A/C	The present F.O.S.-concept is adequate and additional research in this area is not warranted at this time for the following reasons: a) Loads analysis used on rotary wing A/C are far from an exact science - beyond the state of the art. b) Many helicopter components and assemblies are designed to be damage tolerant, crashworthy or fail safe. Since these are ultimate conditions, the F.O.S. does not impact their design. c) Virtually all dynamic components on a helicopter are fatigue critical and not static strength critical. Since fatigue loads are limit loads applied repeatedly, the F.O.S. is not significant in the design of these components. d) Since a helicopter operates in a severe vibration environment, many components are stiffness critical.
SWEDEN, SAAB-SCANIA AIR FORCE MANNED FIXED WING A/C	It is not satisfactory that the F.O.S. of 1.5, which is adequate when the limit load level is based on experience, also is applied when loads in excess of limit loads can hardly be produced.

C. REVIEW AND FUTURE OUTLOOK

C.2	REGARDING F.O.S., IN WHICH AREA IS FURTHER THEORETICAL OR EXPERIMENTAL RESEARCH NEEDED TO CLARIFY UNCERTAINTIES ?
FRANCE AIR FORCE MANNED FIXED WINGA/C	An interesting basis for research seems to be - the improvement of knowledge in flight and ground loads, especially for unsymmetric conditions. - the structural behaviour of composites in service.
GERMANY AIR FORCE/NAVY MANNED FIXED/ VARIABLE,GEOMETRY,A/C	Advanced composites New materials and new manufacturing procedures (RPV) Vibration and acoustic loads (Manned Rotary Wing A/C)
ITALY AIR FORCE MANNED FIXED/ VARIABLE GEOMETRY A/C	Advanced composites and new material processing.
UNITED KINGDOM AIR FORCE/ ARMY/ NAVY ALL AIRCRAFT/ ROTORCRAFT	The above objectives could be achieved if each participating nation expresses the overall safety concept in terms of a breakdown as follows: 1. the margin between release envelope and the unfactored design conditions, 2. the margin between the unfactored design conditions and the factored design conditions, 3. the margin between the weakest aircraft and the average.
UNITED STATES AIR FORCE MANNED FIXED / VARIABLE GEOMETRY A/C	The following two areas may be worthy of further investigation: 1. Establishment of allowable deformation requirements for stability critical structure subjected to exceedances of limit load. 2. Establishment of requirements for primary structure subjected to elevated temperatures.
UNITED STATES ARMY MANNED ROTARY WING A/C MANNED FIXED WING TRANSPORT A/C	- New materials - New material processes
SWEDEN, SAAB-SCANIA AIR FORCE MANNED FIXED WING A/C	Research should be undertaken to establish rational variations of the F.O.S. when the spectrum of loads above limit load varies.

C. REVIEW AND FUTURE OUTLOOK

C.3	TO WHAT EXTENT SHOULD WE CHANGE THE PRESENT-LARGELY DETERMINISTIC-APPROACH TO A PROBABILITY APPROACH?
FRANCE AIR FORCE MANNED FIXED WINGA/C	Up to now we have not researched this question sufficiently.
GERMANY AIR FORCE/ARMY/NAVY MANNED FIXED/ VARIABLE,GEOMETRY,A/C	Probabilistic methods can be applied with advantage, when practical operational information is available in statistical form e.g. manoeuvre loads, gust loads, runway roughness. They are also appropriate, where new technologies, such as active control, lead outside the established scope of the existing deterministic criteria. In these cases we prefer to establish the equivalent level of safety by probability analysis. For RPV-aircraft the design should meet reliability requirements in respect to the planned airspace: restricted area or nonrestricted area.
ITALY AIR FORCE MANNED FIXED/ VARIABLE GEOMETRY A/C	We have not yet sufficient experience to suggest to change the present deterministic approach.
UNITED KINGDOM AIR FORCE/ ARMY/ NAVY ALL AIRCRAFT/ ROTORCRAFT	There is a place for PSD methods in the treatment of fatigue loads-e.g. for runway roughness. However the use of such methods in deriving static design loads is more difficult. We do not believe that a wholly probabilistic approach will be practicable until more is known of individual probabilities involved and their combination at extreme values in small samples.
UNITED STATES AIR FORCE MANNED FIXED / VARIABLE GEOMETRY A/C	For static strength purposes, none, since the data base to make a probabilistic assessment during design of a new weapon system is not adequate and the extreme value probability requirements and our current deterministic requirements would probably result in the same ultimate values and structural components. The reason for this is that the deterministic requirements are not based on unacceptably extreme conditions but on probabilistically described experiences of the past.
UNITED STATES ARMY MANNED ROTARY WING A/C MANNED FIXED WING TRANSPORT A/C	Given the inherent uncertainties in helicopter structural analysis, the addition of probability considerations would only serve to complicate the issue. This approach would require more effort on the part of aircraftcontractors which would be reflected in greater cost to the Army. Significant material benefit to the Army would have to be demonstrated prior to the acceptance of a probabilistic approach.
SWEDEN, SAAB-SCANIA AIR FORCE MANNED FIXED WING A/C	A complete change from F.O.S. to a probability approach cannot, in our view, be accomplished without establishing regulations on how to determine the appreciable amount of data that has to go into probability approach. Rational variations of the F.O.S., established by research and applied via regulations seem a preferable approach. PSD-methods are excellent tools for determining fatigue load spectra but for defining loads for static design, an extreme value approach seems more suitable.

3.0 PRECIS OF ROUND TABLE DISCUSSION

On the basis of the answers to the Questionnaire (Reviewed Evaluation 1st issue) presented by the coordinator at the 51st SMP-Meeting the Sub-Committee had a detailed and fruitful discussion with respresentatives of the military airworthiness authorities. The following precis, highlighting the main points of the round table discussion, has been prepared by W.G. Heath. It is an indication of the emphasis placed by all those present on the lack of understanding of the principles on which the Factor of Safety is based. The topics of the discussion have been related (in brackets) to the numbers of the questions concerned.

3.1 Introduction

At the 51st SMP Meeting, a round table discussion was held at which, besides normal Sub-Committee members, representatives of five military airworthiness authorities were present as follows:

France:	M.M. Sancho Service Technique Aeronautique
Germany:	Dipl.-Ing. M. Hacklinger Bundesamt für Wehrtechnik und Beschaffung
United Kingdom:	Mr. P.R. Guyett Royal Aircraft Establishment
USAF:	Mr. K.I. Collier Air Force Flight Dynamics Laboratory
US Army:	Mr. D. Schrage Army Aviation R&D Command

The discussion centred on the document "Reviewed Evaluation of Questionnaire on Factors of Safety" which had been prepared by the two Coordinators and revised by the European Coordinator (Mr. H. Struck) following his visits to the first three above-named authorities prior to the meeting.

The first question - "What is the factor of safety intended to cover?" caused the most discussion, since it appeared at first sight that those participating held widely different views. Once this question had been resolved, the remaining questions were dealt with more briefly.

3.2 What is the Factor of Safety intended to cover?
(Question A.3 of questionnaire)

3.2.1 Uncertainties in Loads (A.3a)

It was assumed that all countries try to establish the true magnitude of the applied loads, but that some uncertainties may often remain. The question resolved into what was meant by 'uncertainties': were the loads higher than the design cases, or unknowns within the prescribed conditions? Opinion here was divided; some accepted one view, some the other, whilst at least one member felt that the factor should cover both types of uncertainty.

Yet a further opinion was that, whilst one might expect to discover all the unknowns during the development phase, there always remained some 'unknown unknowns' in service, and it was pointed out that the UK, in particular, deducted 10% from the design speed when setting the service speed to allow for these uncertainties.

The discussion led to a corollary to the basic question: Would a reduced factor be applied if all uncertainties were eliminated? It was stated that this was done in some cases by mutual agreement between the design and airworthiness authorities.

Those present then discussed what action should be taken if loads were exceeded in service. Several Air Forces regularly reported such exceedances, and views ranged from the simple one of reprimanding the pilot to conducting a statistical survey. It was felt a large part of the factor could be taken up by flying beyond the stated limits, and one authority was prepared to let regular exceedances go unchecked provided the structure was known to be safe.

The discussion shifted to a consideration of probabalistic versus deterministic design methods, at least one SMP member believing that the arguments heard so far made a clear case in favour of the probabalistic approach to design. However, the purpose of the meeting was to clarify the role of the factor of safety, and since there appeared to be a fundamental disagreement on the question as set, it was agreed to redefine the

question to read - 'Is the factor of safety intended to cover

a) Operational exceedances of design conditions

b) Uncertainties in loads?'

With some qualifications, all participating nations answered 'yes' to both a) and b). The qualifications included, in one case, making a distinction between simple and complex load case, the simple load cases receiving a 'No' to part b), although no change in the factor was to be implied. Another authority stipulated that the answer 'yes' to a) depended on continued monitoring of the service usage. One authority answered a) with no such qualification, in the belief that it was unlikely for the weakest aircraft to meet the biggest loads.

3.2.2 Inaccuracies in Structural Analysis (A.3b)

The Coordinator pointed out that several authorities had revised their answer to this question. It now seemed that the factor was assumed to cover inaccuracies in structural analysis only until representative structural tests took place. All nations had a policy of first making an analysis which was followed by strength tests, but not all points of the structure could be adequately tested, neither could all the design cases be represented, so that the factor must still cover some areas even after the test programme was completed.

If this was so, making analysis the sole route for acceptance of some structural items, how was one to deal with different methods of idealisation? One answer to this question was that most engineers erred on the 'safe side'. In any event, it was difficult to represent the natural load distribution on a test specimen, so that the factor was needed even for those areas which had apparently been thoroughly tested.

The discussion turned to the expectation of all authorities to see the full factor demonstrated during testing. Surely, it was argued, failure at a factor of (say) 1.49 should be acceptable, since the very fact that a test had been made should have eliminated the need for a full factor.

The authorities were not in agreement with this view, stating that the factor had to cover many separate aspects. Thus if only one article was tested to its ultimate load in only one design case, many unknowns still remained. Whilst credit was not given (in the form of a reduced factor) for conducting a test, a debit might be made (in the form of an increased factor) if there were no test at all.

Whilst there were clearly differences in views regarding the role played by the factor in covering uncertainties in loads, all authorities seemed to agree that the factor was used to cover inaccuracies in structural analysis until the tests were complete.

The discussion then turned to the difficulty of answering this question by considering separate aspects which the factor of safety was intended to cover. It was impossible, one authority argued, to cut the 'cake' into such thin slices, ascribing one slice to loads, another to analysis, and so on.

The 'cake' could also be divided not merely into specific subjects, but amongst those who felt entitled to a share. Thus the operator felt that the whole of the factor of safety was to cover his use (or abuse) of the aircraft. The stress engineer believed the factor was entirely to cover the inadequacies of his analysis, whilst the materials engineer and the production engineer had similar claims. It was indeed an unusual cake, which could satisfy all who fed from it! The authorities seemed only too willing to perpetuate the mystique surrounding the factor by allowing each of the parties to continue in his particular belief, and by not attempting to apportion the factor to different aspects.

3.2.3 Deterioration in Service (A.3c)

Whilst all agreed that materials such as composites, which had a serious environmental degradation problem, needed special attention to cover deterioration in service, there was some uncertainty when orthodox materials were discussed.

However, by posing the question 'How is deterioration covered if not by the factor of safety?' the general consensus was reached that the factor was intended for this purpose, i.e. it covered unknown or random deterioration in service. Once such deterioration (eg corrosion) was discovered, it was expected that the affected part would be repaired or replaced so as to restore the original strength without reliance on the factor.

3.2.4 Material and Production Variability (A.3d)

As far as production variability was concerned, there was general agreement that the factor of safety contained an element for this purpose. There was, however, a proviso that there must be no reduction of quality assurance because this element existed.

Two authorities (one not represented at the discussion) believed that the factor should also cover material variability, although the other authorities held the opinion that the scatter in material properties was eliminated within an acceptable probability by the use of 'A' and 'B' values.

The one authority present who was in apparent disagreement with this view modified his answer by stating that the factor should cover material deficiencies only until such time as until they were discovered, when some action should be taken. This policy was in keeping with that for deterioration in service, and was generally accepted.

3.3 Is there a Special Factor of Safety different to those for Normal Operation Conditions? (Question A.5 of questionnaire)

3.3.1 Fail-Safe Conditions (A.5c)

After some discussion, those present agreed that the factor should be at least 1.0 in fail-safe conditions, ie. for the short period between failure of a component and its discovery. Several authorities, notably Germany and the UK, demanded a factor of at least 1.2, whilst two further authorities had not formulated a definite requirement.

3.3.2 Battle Damage (A.5d)

The problem here lay in the definition of 'battle damage', which could encompass everything from a bullet hole to the destruction of the aircraft. Clearly, where the damage was specified, a factor was required. An alternative approach was to have reduced service limits after damage had been incurred.

Where the damage was not specified, the factor was irrelevant. The lack of a definition prompted some authoritites to claim that the question was meaningless, and to call for its deletion.

However, all agreed that if the damage were to be defined, the conditions would be an ultimate one for a brief period of flight with restricted manoeuvres, making the factor 1.0.

3.4 In what way would the Aspects of Damage Tolerance influence the Factor of Safety? (Question A.6 of questionnaire)

One member felt that it was difficult to talk of a factor in this context without specifying the conditions. He felt that the question related only to the residual strength level.

Another opimion was that damage tolerant design could not be translated into a single factor, since this could be anything between 1.0 and 1.5. The application of Damage Tolerant principles did not directly affect the factor of safety. Yet another view was that a factor less than 1.0 was admissible in the case of readily detectable damage.

There was thus some further clarification needed of this question.

4.0 EVALUATION

In this chapter the attempt has been made to evaluate the answers to the questionnaire in the sense that agreements and disagreements are highlighted and - where possible - conclusions are drawn.

A.1 It seems to be general custom that the F.O.S. to be applied for any particular vehicle are defined in one or two of the following documents:

- Aircraft Specification
- System Specification
- Military Design Requirements

Mainly the F.O.S. are defined in the military regulations which are applied

- MIL-Spec's in Germany, Italy and US
- AIR 2004/D, AIR 2004/E in France, Germany
- Av.P. 970 in UK, Germany for Rotary wing A/C

The applicable regulations are listed in the answers as well as any special certification documents.

A.2 In the regulations generally no margin is given between the design conditions and the operational conditions, but the operational envelope has to be covered by the design envelope.

The relation for loads exceptionally stated in the French Norm AIR 2004/D is not contained in the new issue(AIR 2004/E).As yet for aircraft with active controls the existing requirements are considered to be adequate.

A.3 In the following chart a rough suryey is given by (+) marking positive tendency and by (-) marking negative tendency of answer.

It can be seen that most of the answers are in agreement with the exception of part c "Deterioration in service".

A differentiated consideration is given:

- for part a1 and a2 "Uncertainties in loads due to operational exceedances of design conditions" (a1) from Italy and "uncertainties of load analysis" (a2) from Germany.
- for part d "Variability in material" from France.

A.3 IS THE F.O.S. INTENDED TO COVER:

	MILITARY						
	FR	GE	IT	UK	US AF	US/AR	SW
A) 1. OPERATIONAL EXCEEDANCES OF DESIGN CONDITIONS	+	+	– □ + □	+	+	+	+
2. UNCERTAINTIES IN LOADS	+	+ Δ – Δ	+	+	+	+	+
B) INACCURACIES IN STRUCTURAL ANALYSIS	+	+ – *	+	+	+	+	–
C) DETERIORATION IN SERVICE	+	+	–	+	+	–	–
D) VARIABILITY - MATERIAL	+	–	–	–	–	–	–
D) VARIABILITY - PRODUCTION	+	+	+	+	+	+	+
E) SPECIAL ADDITIONAL FACTORS FACTORS ON CASTINGS, FORGINGS, ETC.	+	+	+	+	+	+	+

+) means the tendency of answer is yes -) means the tendency of answer is no

*) After completion of compliance tests.
Δ) Yes, if complicated load case
No , if simple load case
□) No, if resulting from pilot handling
Yes, if deriving from A/C Systems

A.4 a) To this question the answers do not show general agreement: Six answers out of seven state that no additional factors are applied to cover dynamic effects in lieu of rational analysis (FR, GE, IT, UK, USAF, SW), four of the answers expressing that analysis and/or testing have to cover dynamic effects (FR, IT, UK, US-AR). Only one answer states the use of additional factors in lieu of rational analysis (US-AR).

b) In particular cases a dynamic factor is applied to estimate the limit design loads in lieu of rational analysis:

- ground loads (FR, GE, UK)
- gust loads, (UK) applying gust alleviation factors
- ejection seat mountings (UK)
- dynamic overswing (GE) of external stores
- buffet loads (US)
- installed equipment (SW)
- for helicopters several factors (US)

A.5 The figures derived from the answers are given in the following chart. In general the values of the figures agree. There are only slight differences for part (c) "fail safe conditions" (F.O.S. applied between 1.0 and > 1.2). For part (d) "Battle damage conditions" the philisophy seems to be in discussion.

In particular it can be said:

a) Failures during operation.
In general special F.O.S. are not used, failures of control system, engine etc. are covered by design philosophy.

In France and United Kingdom a lower F.O.S. may be applied which is to be agreed with the authority.

b) Concerning the crash landing conditions in the regulations the loads are stated as ultimate loads. There are no answers given for other emergency landing conditions, e. g. lift devices failed etc.

c) In fail safe conditions residual strength requirements are applied.

The load level is stated in the regulation applied or will be stated by the authority; the values vary from limit load (1.0) to not less than 1.2 limit load.

d) For battle damage only a few figures are given.

e,f) Loads due to engine surge, hammershock etc. as well as those for bird impact and disc burst are generally considered as limit loads.

A.6 The answers to this question range from "no influence" to "in discussion" on to the statement that damage tolerance and fracture mechanics concepts tend to lower the stress levels and thus result in higher effective F.O.S. That means that the damage tolerance aspects do not influence the F.O.S. directly.

New requirements are available (USAF, MIL-A-83444) or are being drafted (UK) dealing with cracks and load levels. The load levels are similar to fail safe conditions.

A.7 Normally no different F.O.S. are applied independent of whether the load level is limited by reliable means or defined on the basis of experiences.

A lower F.O.S. can be accepted in special cases:

- for aircraft with particular characteristics
- for cases where it can be proven that 1.5 times limit load is physically not achievable
- in cases which are considered "on their merits"

A.5 DO YOU APPLY SPECIAL F.O.S. DIFFERENT FROM THOSE FOR NORMAL OPERATIONAL CONDITIONS ?

ALL FIGURES GIVEN ARE TOTAL VALUES OF F.O.S.

CONDITIONS	MILITARY						
	FR	GE	IT	UK	US AF	US/AR	SW
A) FAILURE DURING OPERATION	≤1.5 *	1.5	1.5	≤1.5	1.5	1.5	1.5
B) EMERGENCY LANDING	1.0	1.0	1.0	1.0	1.0	1.0	1.0
C) FAIL SAFE	1.0	1.2	NC	≥1.2	≥1.0	1.0	SD
D) BATTLE DAMAGE Δ	NC	DISC.	DISC.	1.5	RS	1.0	SD
E) HAMMERSHOCK, ENGINE SURGE	1.5	1.5	1.5	1.5	1.5	-	1.5
F) STRUCTURAL DAMAGE AS A RESULT OF - BIRD IMPACT	1.0	1.0	-	1.0	1.0	1.0	PS
-DISC BURST	1.0	1.0	-	1.0	1.0	1.0	

*) depending on the failure probability

Δ) only applicable if damage is defined

SD = treated as a separete design condition

PS = for pilot safety only

RS = residual strength requirements

NC = not yet considered

DISC. = special factors in discussion

A.8 The answers to this question show general agreement in stating that the design speed is greater than the operational speed.

The relationship between both speeds is defined in different ways:

- a margin to be chosen by user (FR)
- operational speeds to be a certain amount below the design speed (GE, UK)
- factors to be applied depending on area of problem (USAF, US-AR)
- limiting speeds or design speeds chosen such that their exceedance seems impossible.

A.9 There is general agreement that temperature effects are accounted for by reducing the strength values of the material by using approved Handbooks and applying the normal F.O.S. (with the exception of France).

That means:

- The allowable mechanical strength values of the material are reduced to the temperature reached in service applying the usual F.O.S.
- The thermal stresses are multiplied by the usual proof and ultimate factors. Exceptionally in France a reduced factor of 1.25 is applied.

A.10 The procedure varies and may be summarized as follows:

- No special factors for prototypes and experimental vehicles (FR, IT)
- No special factors are applied, if normal test program is followed (UK)
- Special factors may be applied
  - if reliance is placed on calculation only (UK)
  - to verify the airframe for the usually limited usage USAF)
- For experimental A/C special factors may be applied (GE)
- For Prototypes the reduction of 10% due to manufacturing tolerances may be increased to 16% (SW see A.3)

A.11 In general no special factors are applied to the inlet or to the engine tie down points. Only Sweden applies an extra factor of 1.15 to the engine mounting.

B. Three answers state "No comment". For the four remaining answers the following considerations covering flight safety and airworthiness as a whole may be derived:

- Endurance and confidence tests on aircraft systems or special items
- Vibration testing of IR-suppressor and special components of the A/C-equipment
- Security of fixing doors and panels
- Protection with respect to lightning strike, icing, exhaust gases from weapons, turbine discs in case of non-containment
- Safety and reliability analysis and demonstrations

C 1 The present concept and the values of the F.O.S. are in general regarded to be realistic and satisfactory with the following additional remarks:

- For composite parts additional factors may or must be used to cover the influence of environmental degradation and manufacturing variability (GE)
- The present concept is to be complemented with an effective durability and damage tolerance program , because this concept cannot and was not intended to account for high intensity cyclic loading (USAF)
- Present concept could be revised following state of the art improvements (IT)
- An international rationalisation of factors is timely to achieve more uniform standards of safety and, possibly, increased operational effectiveness (UK)
- The normal F.O.S. of 1.5 is not satisfactory for cases where loads in excess of limit loads can hardly be produced (SW)

C.2 The answers show up the need for a series of theoretical and experimental research to clarify uncertainties with respect to F.O.S.:

- Improvement of knowledge about flight and ground loads, especially for unsymmetric conditions (FR)
- The structural in service behaviour of new materials, especially advanced composites (FR)
- New material processing (IT, US-AR)
- Each participating nation to express the overall safety concept in terms of the following breakdown: (UK)
  - margin between release envelope and unfactored design conditions
  - margin between unfactored design conditions and factored design conditions
  - margin between the weakest aircraft and the average one
- Allowable deformation requirements for stability critical structure subjected to exceedances of limit load (USAF)
- Requirements for primary structures subjected to elevated temperatures (USAF)
- Establish rational variations of F.O.S. when the spectrum of loads above limit load varies (SW)

C.3 None of the answers is in favour of any direct change to the present concept of structural safety.

On the other hand the probabilistic methods in general, and the PSD-methods especially,are regarded to be a valuable tool for fatigue loads and the extreme value approach seems suitable for defining static design loads.

Before thinking of changing the present largely deterministic approach to a probabilistic approach more should be known about

- invidual probabilities involved and their combination at extreme values in small samples (UK)
- how to determine the appreciable amount of data that has to go into probability approach (SW)
- practical operational data with enough information in statistical form for manoeuvre loads, gust loads, runway roughness (GE, USAF)
- new technologies which go outside the established scope of the existing deterministic criteria e. g. active control (GE)

Rational variation of the F.O.S. based on research - as already mentioned under C2 - seems to be a preferable approach.

REPORT DOCUMENTATION PAGE

1. Recipient's Reference	2. Originator's Reference	3. Further Reference	4. Security Classification of Document
	AGARD-R-677	ISBN 92-835-1390-8	UNCLASSIFIED

5. Originator
Advisory Group for Aerospace Research and Development
North Atlantic Treaty Organization
7 rue Ancelle, 92200 Neuilly sur Seine, France

6. Title
FACTORS OF SAFETY RELATED TO STRUCTURAL INTEGRITY
A Review of Data from Military Airworthiness Authorities

7. Presented at

8. Author(s)/Editor(s)	9. Date
	June 1981

10. Author's/Editor's Address	11. Pages
	43

12. Distribution Statement
This document is distributed in accordance with AGARD policies and regulations, which are outlined on the Outside Back Covers of all AGARD publications.

13. Keywords/Descriptors

Military aircraft
Airworthiness
Airframes
Fuselages
Safety engineering
Aviation safety

14. Abstract

The concept of structural safety as presently applied by the military airworthiness authorities of the main NATO-Member-Countries has proven satisfactory, though being far from having a rational basis.

Before this background, a Sub-Committee of SMP established a Questionnaire ~~(see chapter 1)~~, asking the military authorities for all numerical factors applied to ensure structural safety of aircraft. The answers given ~~are condensed in chapter 2 of this report~~, including the results of personal discussions between coordinators and nominated representatives of the authorities. The précis of the round table discussion as well as an evaluation of answers and discussion are included for reasons of completeness.

From the evaluation it may be concluded that there exists a considerable amount of agreement with respect to the Factors of Safety and their application. On the other hand, some disagreements and different interpretations have resulted. Thus this report forms a basis for discussing the disagreements in order to achieve a higher degree of conformity between the authorities of the NATO-Countries with regard to structural safety and reliability.

This Report was sponsored by the Structures and Materials Panel of AGARD.

AGARD Report No.677
Advisory Group for Aerospace Research and Development, NATO
FACTORS OF SAFETY RELATED TO STRUCTURAL INTEGRITY – A Review of Data from Military Airworthiness Authorities
Published June 1981
43 pages

The concept of structural safety as presently applied by the military airworthiness authorities of the main NATO-Member-Countries has proven satisfactory, though being far from having a rational basis.

Before this background, a Sub-Committee of SMP established a Questionnaire (see chapter 1), asking the

P.T.O.

AGARD-R-677

Military aircraft
Airworthiness
Airframes
Fuselages
Safety engineering
Aviation safety

AGARD Report No.677
Advisory Group for Aerospace Research and Development, NATO
FACTORS OF SAFETY RELATED TO STRUCTURAL INTEGRITY – A Review of Data from Military Airworthiness Authorities
Published June 1981
43 pages

The concept of structural safety as presently applied by the military airworthiness authorities of the main NATO-Member-Countries has proven satisfactory, though being far from having a rational basis.

Before this background, a Sub-Committee of SMP established a Questionnaire (see chapter 1), asking the

P.T.O.

AGARD-R-677

Military aircraft
Airworthiness
Airframes
Fuselages
Safety engineering
Aviation safety

AGARD Report No.677
Advisory Group for Aerospace Research and Development, NATO
FACTORS OF SAFETY RELATED TO STRUCTURAL INTEGRITY – A Review of Data from Military Airworthiness Authorities
Published June 1981
43 pages

The concept of structural safety as presently applied by the military airworthiness authorities of the main NATO-Member-Countries has proven satisfactory, though being far from having a rational basis.

Before this background, a Sub-Committee of SMP established a Questionnaire (see chapter 1), asking the

P.T.O.

AGARD-R-677

Military aircraft
Airworthiness
Airframes
Fuselages
Safety engineering
Aviation safety

AGARD Report No.677
Advisory Group for Aerospace Research and Development, NATO
FACTORS OF SAFETY RELATED TO STRUCTURAL INTEGRITY – A Review of Data from Military Airworthiness Authorities
Published June 1981
43 pages

The concept of structural safety as presently applied by the military airworthiness authorities of the main NATO-Member-Countries has proven satisfactory, though being far from having a rational basis.

Before this background, a Sub-Committee of SMP established a Questionnaire (see chapter 1), asking the

P.T.O.

AGARD-R-677

Military aircraft
Airworthiness
Airframes
Fuselages
Safety engineering
Aviation safety

military authorities for all numerical factors applied to ensure structural safety of aircraft. The answers given are condensed in chapter 2 of this report, including the results of personal discussions between coordinators and nominated representatives of the authorities. The précis of the round table discussion as well as an evaluation of answers and discussion are included for reasons of completeness.

From the evaluation it may be concluded that there exists a considerable amount of agreement with respect to the Factors of Safety and their application. On the other hand, some disagreements and different interpretations have resulted. Thus this report forms a basis for discussing the disagreements in order to achieve a higher degree of conformity between the authorities of the NATO-Countries with regard to structural safety and reliability.

This Report was sponsored by the Structures and Materials Panel of AGARD.

ISBN 92-835-1390-8

military authorities for all numerical factors applied to ensure structural safety of aircraft. The answers given are condensed in chapter 2 of this report, including the results of personal discussions between coordinators and nominated representatives of the authorities. The précis of the round table discussion as well as an evaluation of answers and discussion are included for reasons of completeness.

From the evaluation it may be concluded that there exists a considerable amount of agreement with respect to the Factors of Safety and their application. On the other hand, some disagreements and different interpretations have resulted. Thus this report forms a basis for discussing the disagreements in order to achieve a higher degree of conformity between the authorities of the NATO-Countries with regard to structural safety and reliability.

This Report was sponsored by the Structures and Materials Panel of AGARD.

ISBN 92-835-1390-8

military authorities for all numerical factors applied to ensure structural safety of aircraft. The answers given are condensed in chapter 2 of this report, including the results of personal discussions between coordinators and nominated representatives of the authorities. The précis of the round table discussion as well as an evaluation of answers and discussion are included for reasons of completeness.

From the evaluation it may be concluded that there exists a considerable amount of agreement with respect to the Factors of Safety and their application. On the other hand, some disagreements and different interpretations have resulted. Thus this report forms a basis for discussing the disagreements in order to achieve a higher degree of conformity between the authorities of the NATO-Countries with regard to structural safety and reliability.

This Report was sponsored by the Structures and Materials Panel of AGARD.

ISBN 92-835-1390-8

military authorities for all numerical factors applied to ensure structural safety of aircraft. The answers given are condensed in chapter 2 of this report, including the results of personal discussions between coordinators and nominated representatives of the authorities. The précis of the round table discussion as well as an evaluation of answers and discussion are included for reasons of completeness.

From the evaluation it may be concluded that there exists a considerable amount of agreement with respect to the Factors of Safety and their application. On the other hand, some disagreements and different interpretations have resulted. Thus this report forms a basis for discussing the disagreements in order to achieve a higher degree of conformity between the authorities of the NATO-Countries with regard to structural safety and reliability.

This Report was sponsored by the Structures and Materials Panel of AGARD.

ISBN 92-835-1390-8

AGARD

NATO OTAN

7 RUE ANCELLE · 92200 NEUILLY-SUR-SEINE

FRANCE

Telephone 745.08.10 · Telex 610176

DISTRIBUTION OF UNCLASSIFIED AGARD PUBLICATIONS

AGARD does NOT hold stocks of AGARD publications at the above address for general distribution. Initial distribution of AGARD publications is made to AGARD Member Nations through the following National Distribution Centres. Further copies are sometimes available from these Centres, but if not may be purchased in Microfiche or Photocopy form from the Purchase Agencies listed below.

NATIONAL DISTRIBUTION CENTRES

BELGIUM
Coordonnateur AGARD – VSL
Etat-Major de la Force Aérienne
Quartier Reine Elisabeth
Rue d'Evere, 1140 Bruxelles

CANADA
Defence Science I
Department of Na
Ottawa, Ontario K

DENMARK
Danish Defence R
Østerbrogades Kas
Copenhagen Ø

FRANCE
O.N.E.R.A. (Direc
29 Avenue de la D
92320 Châtillon sc

GERMANY
Fachinformationsz
Physik, Mathemati
Kernforschungszen
D-7514 Eggenstein-

GREECE
Hellenic Air Force
Research and Devel
Holargos, Athens

ICELAND
Director of Aviation
c/o Flugrad
Reykjavik

ITALY
Aeronautica Militare
Ufficio del Delegato Nazionale all'AGARD
3, Piazzale Adenauer

National Aeronautics and Space Administration
WASHINGTON, D C 20546

OFFICIAL BUSINESS
Penalty For Private Use, $300 00

POSTAGE AND FEES PAID
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
NASA-451

SPECIAL FOURTH CLASS MAIL
BOOK

0 2 4B,7, 082481 S02672DS
DEPT OF DEFENSE
DEFENSE TECHNICAL INFORMATION CENTER
ATTN: DTIC-DDA-2
CAMERON STATION BLDG 5
ALEXANDRIA VA 22314

E)
Ministry of National Defence, Ankara

UNITED KINGDOM
Defence Research Information Centre
Station Square House
St. Mary Cray
Orpington, Kent BR5 3RE

UNITED STATES
National Aeronautics and Space Administration (NASA)
Langley Field, Virginia 23365
Attn: Report Distribution and Storage Unit

THE UNITED STATES NATIONAL DISTRIBUTION CENTRE (NASA) DOES NOT HOLD STOCKS OF AGARD PUBLICATIONS, AND APPLICATIONS FOR COPIES SHOULD BE MADE DIRECT TO THE NATIONAL TECHNICAL INFORMATION SERVICE (NTIS) AT THE ADDRESS BELOW.

PURCHASE AGENCIES

Microfiche or Photocopy
National Technical
Information Service (NTIS)
5285 Port Royal Road
Springfield
Virginia 22161, USA

Microfiche
Space Documentation Service
European Space Agency
10, rue Mário Nikis
75015 Paris, France

Microfiche
Technology Reports
Centre (DTI)
Station Square House
St. Mary Cray
Orpington, Kent BR5 3RF
England

Requests for microfiche or photocopies of AGARD documents should include the AGARD serial number, title, author or editor, and publication date. Requests to NTIS should include the NASA accession report number. Full bibliographical references and abstracts of AGARD publications are given in the following journals:

Scientific and Technical Aerospace Reports (STAR)
published by NASA Scientific and Technical
Information Facility
Post Office Box 8757
Baltimore/Washington International Airport
Maryland 21240; USA

Government Reports Announcements (GRA)
published by the National Technical
Information Services, Springfield
Virginia 22161, USA

Printed by Technical Editing and Reproduction Ltd
Harford House, 7–9 Charlotte St, London W1